



**JP10048673A**

**ELECTROPHORETIC RECORDING MEDIUM AND ELECTROPHORETIC DISPLAY  
DEVICE**

**FUJI XEROX CO LTD**

**Inventor(s): ; TSUDA DAISUKE**

**Application No. 08206977, Filed 19960806, Published 19980220**

**Abstract:** PROBLEM TO BE SOLVED: To provide an electrophoretic recording medium which is capable of forming images having high resolution at a high speed and is simple in constitution and low in cost and allows the comparison of plural static images and an electrophoretic display device.

**SOLUTION:** The formation of the plural static images to be compared is made possible by the simple and inexpensive constitution consisting of one driving device 2A and the plural recording media 1A by making the recording media 1A separable from the driving device 2A. A non-display side substrate 12 having electrical conductivity anisotropy in a thickness direction and surface electrodes 13 come into contact with a dispersion system 16 and, therefore, the formation of the images having the high resolution is made possible by the min. impressed voltage. The combinations of the electrodes for impressing the electric fields on the dispersion system 16 are specified to the combinations of the surface electrodes and the electrode groups in the matrix form or the combinations of the plural wire-shaped electrodes in a longitudinal direction or transverse direction and the plural wireshaped electrodes in the transverse direction or the longitudinal direction, by which the two-dimensional driving in the matrix form is made possible and the writing of the images at a high speed on the recording media 1A is made possible.

**Int'l Class:** G02F001167 G09F00937

**MicroPatent Reference Number:** 000081727

**COPYRIGHT:** (C) 1998JPO

---

**SHUSAKU YAMAMOTO**

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

(Translation)

Laid-Open Publication Number: 10-48673

Laid-Open Publication Date: February 20, 1998

Title of the Invention: ELECTROPHORETIC RECORDING MEMBER  
AND ELECTROPHORETIC DISPLAY DEVICE

Application Number: 8-206977

Filing Date: August 6, 1996

Inventor: DAISUKE TSUDA

Applicant: FUJI XEROX CO,

[Claims]

[Claim 1] An electrophoretic recording medium, comprising:

an anisotropically conductive electrode being conductive in a thickness direction thereof and not conductive in a vertical width direction and a lateral width direction thereof:

a counter electrode opposing the anisotropically conductive electrode with a predetermined gap therebetween, thereby providing a predetermined space between the counter electrode and the anisotropically conductive electrode: and

a dispersion system contained in the space and obtained by dispersing a plurality of electrophoretic particles in a dispersion medium, wherein

an image is displayed by an electric field according to an image signal applied between the anisotropically conductive electrode and the counter electrode, and the image is retained after the electric field is removed.

**SHUSAKU YAMAMOTO**

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

[Claim 2] An electrophoretic recording medium according to claim 1, wherein the counter electrode is one of a planar electrode, a plurality of vertical linear electrodes, a plurality of lateral linear electrodes and a group of electrodes arranged in a matrix.

[Claim 3] An electrophoretic recording medium according to claim 1, wherein at least one of the anisotropically conductive electrode and the counter electrode is a transparent electrode.

[Claim 4] An electrophoretic recording medium according to claim 1, wherein the counter electrode is an anisotropically conductive electrode being conductive in a thickness direction thereof and not conductive in a vertical width direction and a lateral width direction thereof.

[Claim 5] An electrophoretic recording medium according to claim 1 or 4, wherein the anisotropically conductive electrode is a transparent electrode obtained by dispersing a plurality of conductive transparent particles in a transparent resin, and the transparent resin and the plurality of conductive transparent particles have substantially the same refractive index.

[Claim 6] An electrophoretic display device, comprising: an electrophoretic recording medium comprising an anisotropically conductive electrode being conductive in a thickness direction thereof and not conductive in a vertical width direction and a lateral width direction thereof, a counter electrode opposing the anisotropically conductive electrode with a predetermined gap

**SHUSAKU YAMAMOTO**

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

therebetween, thereby providing a predetermined space between the counter electrode and the anisotropically conductive electrode, and a dispersion system contained in the space and obtained by dispersing a plurality of electrophoretic particles in a dispersion medium, wherein an image is displayed by an electric field according to an image signal applied between the anisotropically conductive electrode and the counter electrode, and the image is retained after the electric field is removed: and a driver removably assembled with the electrophoretic recording medium, the driver comprising a driving electrode which is in contact with the anisotropically conductive electrode when the electrophoretic recording medium is attached, and application means for applying, via the driving electrode, the electric field according to the image signal between the anisotropically conductive electrode and the counter electrode.

[Claim 7] An electrophoretic display device according to claim 6, wherein the counter electrode and the driving electrode comprise a combination of a planar electrode and a group of electrodes arranged in a matrix or a combination of a plurality of vertical or lateral linear electrodes and a plurality of lateral or vertical linear electrodes.

[Claim 8] An electrophoretic display device according to claim 6, wherein at least either the anisotropically conductive electrode and the driving electrode or the counter electrode is(are) a transparent electrode(s).

**SHUSAKU YAMAMOTO**

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

[Claim 9] An electrophoretic display device according to claim 6, wherein:

the counter electrode is an anisotropically conductive electrode being conductive in a thickness direction thereof and not conductive in a vertical width direction and a lateral width direction thereof: and

the driver comprises another driving electrode which is in contact with the counter electrode when the electrophoretic recording medium is attached, with the application means applying the electric field to the counter electrode via the other driving electrode.

[Claim 10] An electrophoretic display device according to claim 9, wherein: the driving electrode and the other driving electrode comprise a combination of a planar electrode and a group of electrodes arranged in a matrix or a combination of a plurality of vertical or lateral linear electrodes and a plurality of lateral or vertical linear electrodes.

[Claim 11] An electrophoretic display device according to claim 9, wherein at least either the anisotropically conductive electrode and the driving electrode or the counter electrode and the other driving electrode are transparent electrodes.

[Claim 12] An electrophoretic display device according to claim 6 or 9, wherein the anisotropically conductive electrode is a transparent electrode obtained by dispersing a plurality of conductive transparent particles in a transparent resin, and the transparent resin and the plurality of conductive transparent particles have substantially the same refractive index.

**SHUSAKU YAMAMOTO**

Your Ref: 2108/2

Japanese Laid-Open Publication **No.** 10-48673

[Detailed Description of the Invention]

[0001]

[Field of the Invention] The present invention relates to an electrophoretic recording medium and an electrophoretic display device utilizing an electrophoresis phenomenon and, in particular, to an electrophoretic recording medium and an electrophoretic display device in which an electrophoretic recording medium and a driver can be separated from each other.

[0002]

[Prior Art] The "electrophoresis phenomenon" is based on an electric double layer which is typically produced at an interface between a solid (an electrophoretic particle) and a liquid (a dispersion medium). An electric charge is provided on the surface of the particle according to the combination of materials of the particle and the dispersion medium and the action of a surfactant added to the dispersion medium. The particle migrates in a desired direction at a desired speed using a force applied to the charge on the surface thereof as a driving force.

[0003] A display mode utilizing such an electrophoresis phenomenon is simple in structure and has a wide selection of display colors, high contrast, a wide viewing angle, a low driving voltage, low power consumption and an image memory property, thereby providing various functions which are difficult to achieve with a CRT display or an LCD. For example, it is possible to clearly display images with frequent changes, and to continu-

**SHUSAKU YAMAMOTO**

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

ously display a still image based on the image memory property with no supply energy.

[0004] Conventional electrophoretic display devices can be generally classified by the driving mode into: those of a mode where an image signal is directly applied from a pair of electrodes in contact with a dispersion system to the dispersion system (a direct application mode) (e.g., Japanese Patent Laid-Open Publication No. 6-148693): and those of a mode where a dispersion system is provided between an insulative plate and an electrode, and an outer surface of the insulative plate is irradiated with an ion flow by ion flow irradiation means so as to indirectly apply an image signal from outside of the insulative plate to the dispersion system (an indirect application mode) (e.g., Japanese Patent Laid-Open Publication No. 61-86780, Japanese Patent Laid-Open Publication No. 6-202168).

[0005] The conventional electrophoretic display device employing the direct application mode can produce a high resolution image with a minimum applied voltage since the electrode is in contact with the dispersion system, while a matrix two-dimensional driving can easily be conducted, thereby being suitable for a high-speed write operation.

[0006] In the conventional electrophoretic display device employing the indirect application mode, the electrophoretic recording medium having the dispersion system is separated from the ion flow irradiation means, so that the electrophoretic recording medium does not need to have a group of electrodes, whereby the electropho-

## SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

retic recording medium is simple and inexpensive. Therefore, a plurality of screens can be viewed at the same time by exchanging only the electrophoretic recording media while using the same ion flow irradiation means, whereby a plurality of screens can easily and inexpensively be produced one after another.

[0007]

[Problems to be Solved by the Invention] However, in the conventional electrophoretic display device employing the direct application mode, the group of electrodes arranged in a matrix are integrated with the electrophoretic recording medium. Therefore, the conventional electrophoretic display device is not significantly different from, e.g., a twisted nematic type liquid crystal display. For example, there was an inconvenience in that in order to view a plurality of screens at the same time, it is necessary to display only parts of screens using the maximum number of pixels which can be used or to provide a plurality of display devices. Thus, other than utilizing the memory property for the sake of a driving operation, e.g., rewriting only a changed portion of an image, thereby suppressing a flicker on the screen, and reducing the power consumption, the memory property was only utilized to retain the written image unchanged for a certain period of time, during which the driver, which is a relatively expensive component had to stop operating.

[0008] Moreover, in the conventional electrophoretic display device employing the indirect application mode, it is difficult to arrange an ion source and an ion flow control blade of the ion flow irradiation means in a ma-



## SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

trix two-dimensional arrangement which is required for high-speed write operations, and it is also difficult to instantaneously invert the polarity of the ion irradiation. Thus, such a conventional electrophoretic display device is not suitable for high-speed driving. Moreover, since a signal is applied for driving the dispersion system via the insulative plate, the resolution is likely to deteriorate.

[0009] Therefore, an object of the present invention is to provide an electrophoretic recording medium and an electrophoretic display device which is capable of providing high resolution images at a high speed and allows for comparison among a plurality of still images with a simple and inexpensive structure.

[0010]

[Means for Solving the Problems] In order to achieve the object, the present invention provides an electrophoretic recording medium, comprising: an anisotropically conductive electrode being conductive in a thickness direction thereof and not conductive in a vertical width direction and a lateral width direction thereof: a counter electrode opposing the anisotropically conductive electrode with a predetermined gap therebetween, thereby providing a predetermined space between the counter electrode and the anisotropically conductive electrode: and a dispersion system contained in the space and obtained by dispersing a plurality of electrophoretic particles in a dispersion medium, wherein an image is displayed by an electric field according to an image signal applied between the anisotropically conductive electrode and the counter electrode, and the image

## SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

is retained after the electric field is removed. With such a structure, when an electric field according to an image signal is applied between the anisotropically conductive electrode and the counter electrode, the electrophoretic particles migrate in the dispersion medium due to the polarity of the charge on the electrophoretic particles and the polarity of the applied electric field, and the electrophoretic particles gather along the anisotropically conductive electrode or the counter electrode. By using a color for the electrophoretic particles which is different from the color used for the dispersion medium, images are visually displayed. By providing the counter electrode of the recording medium as an electrode which covers the entire surface or an anisotropically conductive electrode which also functions as a substrate, the recording medium can be made in a simple and inexpensive structure, thereby providing a simpler and less expensive structure for producing a plurality of still images. Since the anisotropically conductive electrode and the counter electrode are in contact with the dispersion system, a high resolution image can be produced with a minimum applied voltage.

[0011] In order to achieve the above object, the present invention also provides an electrophoretic display device, comprising: an electrophoretic recording medium, comprising an anisotropically conductive electrode being conductive in a thickness direction thereof and not conductive in a vertical width direction and a lateral width direction thereof, a counter electrode opposing the anisotropically conductive electrode with a predetermined gap therebetween, thereby providing a predetermined space between the counter electrode and the ani-

## SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

sotropically conductive electrode, and a dispersion system contained in the space and obtained by dispersing a plurality of electrophoretic particles in a dispersion medium, wherein an image is displayed by an electric field according to an image signal applied between the anisotropically conductive electrode and the counter electrode, and the image is retained after the electric field is removed: and a driver removably assembled with the electrophoretic recording medium, the driver comprising a driving electrode which is in contact with the anisotropically conductive electrode when the electrophoretic recording medium is attached, and application means for applying, via the driving electrode, the electric field according to the image signal between the anisotropically conductive electrode and the counter electrode. With such a structure, when the electrophoretic recording medium is attached to the driver so that the anisotropically conductive electrode of the electrophoretic recording medium contacts the driving electrode of the driver, the anisotropically conductive electrode and the driving electrode are switched to a conductive state. In this state, when the application means applies an electric field according to an image signal between the anisotropically conductive electrode and the counter electrode via the driving electrode, the electrophoretic particles migrate in the dispersion medium due to the polarity of the charge on the electrophoretic particles and the polarity of the applied electric field, and the electrophoretic particles gather along the anisotropically conductive electrode or the counter electrode. Moreover, it is possible to continuously display the image after the electric field applied to the dispersion system is removed, whereby a plurality of still images

## SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

can be compared by exchanging only the electrophoretic recording media while using the same driver, whereby a plurality of still images can be produced one after another. When the electrophoretic recording medium can be separated from the driver, a plurality of still images to be compared with one another can be produced with a simple and inexpensive structure comprising a single driver and a plurality of recording media, rather than using a plurality of display devices each including a recording medium. By employing a combination of a planar electrode and a group of electrodes arranged in a matrix or a combination of a plurality of vertical or lateral linear electrodes and a plurality of lateral or vertical linear electrodes, as an electrode combination for applying an electric field to the dispersion system, it is possible to conduct matrix two-dimensional driving, thereby writing images to the recording medium at a high speed. Thus, the present invention takes advantage of the conventional direct application mode, such as the high resolution property and the high speed property, and takes advantage of the conventional indirect application mode, such as the simplicity of the recording medium and the image comparison capability, while solving the problems associated with these modes.

[0012]

[Embodiments of the Invention] Hereinafter, embodiments of the present invention will be described in detail with reference to the figures. Figure 1 is a cross-sectional view illustrating a structure of an electrophoretic recording medium according to the first embodiment of the invention.

## SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

[0013] The electrophoretic recording medium (hereinafter, referred to simply as the "recording medium") **1A** comprises: a display side substrate **11** and a non-display side substrate **12**, as an anisotropically conductive electrode, held together via a spacer **10**; a planar electrode **13** as a counter electrode provided on an inner surface **11a** of the display side substrate **11**; a dispersion system **16** contained between the substrates **11** and **12**, the dispersion system **16** comprising a dispersion medium **14** and a plurality of electrophoretic particles **15**; and a connector **17** connected to the planar electrode **13**.

[0014] The spacer **10** is made of, for example, a polyester film, or the like, and is provided at the end of the substrates **11** and **12** and, as necessary, in the dispersion system **16**.

[0015] The display side substrate **11** is made of, for example, a transparent glass, plastic, or the like.

[0016] Figure 2 is a plan view illustrating an important part of the non-display side substrate **12**. The non-display side substrate **12** is obtained by dispersing a plurality of conductive particles **12b** in a film **12a**, as illustrated in Figure 2. An area where the conductive particles **12b** are present has an anisotropic conductivity such that it is conductive in the thickness direction thereof due to the conduction effect thereof and not conductive in the vertical width direction and the lateral width direction. As the non-display side substrate **12** is provided on the non-display side, any of various resins can be used for the film **12a**, and any of

## SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

various particles such as nickel particles, carbon particles, glass or plastic particles whose surface has been processed to be conductive.

[0017] The planar electrode 13 is made of an optically transmissive and electrically conductive thin film such as an iridium tin oxide (ITO).

[00181] The dispersion medium 14 may be an insulative organic solvent, such as an isoparaffin-type hydrocarbon, hexylbenzene, tetrafluorodibromoethane, perfluoropolyether or toluenetrifluoride, mixed with a blue dye and an ionic surfactant.

[0019] The electrophoretic particles 15 may be particles obtained by dispersing a white pigment (e.g.,  $\text{TiO}_2$ ) in a transparent wax, and may have a diameter of several  $\mu\text{m}$ , for example.

[00201] Figure 3 is a cross-sectional view illustrating a structure of the electrophoretic display device according to the first embodiment of the invention to which the recording medium 1A illustrated in Figure 1 is applied. The electrophoretic display device (hereinafter, referred to simply as the "display device") 100A comprises the recording medium 1A illustrated in Figure 1 and a driver 2A for driving the recording medium 1A to conduct a display based on the electrophoretic phenomenon, wherein the recording medium 1A and the driver 2A can be separated from each other.

[0021] The driver 2A comprises: a non-display side substrate 20: a group of electrodes 21 arranged in a matrix

## SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

provided as driving electrodes which contact the non-display side substrate 12 of the recording medium **1A** when the recording medium **1A** is attached: a grounded connector which is connected to the connector **17** of the recording medium **1A**; and a power supply circuit 23 for applying a DC voltage between the group of electrodes 21 and the planar electrode **13** of the recording medium **1A**.

[0022] The group of electrodes 21 are provided in a matrix via an insulative region **21a**, and are driven by thin film transistors.

[0023] The power supply circuit 23 applies a DC voltage (an electric field) according to an input signal S to the group of electrodes 21 via a lead **23a**.

[0024] Next, an operation of the present display device **100A** will be described with reference to Figures 4 and 5. Figures 4 and 5 are cross-sectional views illustrating a display state of the recording medium **1A** of the present display device **100A**. It is assumed herein that the electrophoretic particles 15 are negatively charged and floating in the dispersion medium 14, as illustrated in Figure 1.

[0025] An operator attaches the recording medium **1A** illustrated in Figure 1 to the driver 2A, as illustrated in Figure 3. In particular, the non-display side substrate 12 of the recording medium **1A** is placed into contact with the group of electrodes 21 of the driver **2A** so as to connect the connector 17 of the recording medium **1A** with the connector 22 of the driver 2. By placing the non-display side substrate 12 into contact with

## SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

the group of electrodes 21, the non-display side substrate 12 and the group of electrodes 21 will be conductive due to the anisotropic conductivity of the non-display side substrate 12.

[0026] In this state, when the image signal S is externally input, the power supply circuit 23 applies to the group of electrodes 21 a DC voltage (an electric field) of a positive or negative polarity according to the image signal S. Then, as illustrated in Figure 4, the electrophoretic particles 15 located between the group of electrodes 21, to which a negative DC voltage is applied, and the planar electrode 13 migrate in the dispersion medium 14 to gather along the planar electrode 13, whereas the electrophoretic particles 15 located between the group of electrodes 21, to which a positive DC voltage is applied, and the planar electrode 13 migrate in the dispersion medium 14 to gather along the group of electrodes 21.

[0027] From outside of the display side substrate 11, the color of the electrophoretic particles 15 (white in this embodiment) is seen in regions (pixels) where the electrophoretic particles 15 have gathered on the side of the planar electrode 13, while the color of the dispersion medium 14 (blue in this embodiment) is seen in regions (pixels) where the electrophoretic particles 15 have not gathered. Thus, images consisting of two colors, i.e., white and blue, are visually displayed on the side of the display side substrate 11. Due to the image memory property, it is possible with no power supply to continuously display a still image on the side of the display side substrate 11 for a long period of time even



## SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

after the connectors 17 and 22 are disconnected, as illustrated in Figure 5. Therefore, a plurality of still images can be compared with one another by exchanging only the recording media 1A while using the same driver 2A, thereby producing a plurality of still images one after another.

[0028] With the display device 100A having such a structure, image data can be written to the recording medium 1A only by arranging the recording medium 1A in contact with the non-display side substrate 20 of the driver 2A in which the group of electrodes 21 are provided and by connecting the connectors 17 and 22, thereby applying an electric field in a pattern according to the image signal to the recording medium 1A. Moreover, it is possible to continuously display the image after the electric field applied to the dispersion system 16 is removed. Therefore, by providing the recording medium 1A so that it can be separated from the driver 2A, it is possible to produce a plurality of still images to be compared to one another with a simple and inexpensive structure comprising a single driver 2 and a plurality of recording media 1A, rather than using a plurality of display devices each including a recording medium. Moreover, since the recording medium 1A does not have a group of electrodes arranged in a matrix or a plurality of vertical or lateral linear electrodes, the recording medium 1A has a simple and inexpensive structure, thereby providing a simpler and less expensive structure for producing a plurality of still images. Furthermore, since the non-display side substrate 12 and the planar electrode 13 are in contact with dispersion system 16, a recording voltage is directly transferred

## SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

to the interface with respect to the dispersion medium 14 while maintaining the resolution of the group of electrodes 21 due to the conductive particles **12b** being in contact with the group of electrodes 21, whereby it is possible to produce a high resolution image with a minimum applied voltage. Moreover, since a combination of the planar electrode 13 and the group of electrodes **21** arranged in a matrix is employed as the electrode combination for applying an electric field to the dispersion system 16, it is possible to conduct matrix two-dimensional driving and thus to write an image to the recording medium **1A** at a high speed.

[0029] Figure 6 is a cross-sectional view illustrating a structure of an electrophoretic recording medium according to the second embodiment of the present invention. In the figure, the elements having the same functions as those of the recording medium **1A** of Figure 1 are denoted by the same reference numerals and will not further be described. The recording medium **1B** comprises: a display side substrate 18, as a counter electrode, and a non-display side substrate 12, as an anisotropically conductive electrode, held together via a spacer **10**; and the dispersion system 16 comprising the dispersion medium 14 and a plurality of the electrophoretic particles 15 contained between the substrates 18 and **12**.

[0030] As the non-display side substrate 12, the display side substrate 18 is obtained by dispersing a plurality of conductive particles **18b** in a film **18a**. An area where the conductive particles **18b** are present has an anisotropic conductivity so that it is conductive in the thickness direction of the substrate 18 due to the

## SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

conduction effect. As the display side substrate 18 is provided on the display side, a transparent resin can be used for the film 18a, and the conductive particles 18b may be particles obtained by forming a transparent conductive film of, for example, an indium oxide, on the surface of a transparent particle of a glass, plastic, or the like. In such a case, it is preferable for preventing images from being skewed that the transparent film 18a and the transparent conductive particles 18b have substantially the same refractive index.

[0031] Figure 7 is a cross-sectional view illustrating a structure of an electrophoretic display device according to the second embodiment of the present invention to which the recording medium 1B illustrated in Figure 6 is applied. In the figure, the elements having the same functions as those of the display device 100A of Figure 3 are denoted by the same reference numerals and will not further be described. The display device 100B comprises the recording medium 1B illustrated in Figure 6 and a driver 2B for driving the recording medium 1B to conduct a display based on the electrophoretic phenomenon, wherein the recording medium 1B and the driver 2B can be separated from each other.

[0032] The driver 2B comprises: a pair of substrates containing a display side substrate 24 and non-display side substrate 20: a plurality of vertical linear electrodes 25 and a plurality of lateral linear electrodes 26 provided respectively on opposing surfaces 24a and 20a of the pair of substrates containing the display side substrate 24 and non-display side substrate 20 for serving as driving electrodes in contact with the dis-

## SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

play side substrate 18 and the non-display side substrate 12 of the recording medium **1B** when the recording medium **1B** is attached: and a power supply circuit 27 for applying a DC voltage between the electrodes 25 and 26 according to the image signal.

**[0033]** The plurality of vertical linear electrodes 25 on the display side are provided via an insulative region (not shown), and are made of an optically transmissive and electrically conductive thin film such as an iridium tin oxide (ITO). The vertical linear electrodes 25 are driven by thin film transistors.

**[0034]** The plurality of lateral linear electrodes 26 on the non-display side are formed via an insulative region 26a, and are driven by thin film transistors.

**[0035]** The power supply circuit 27 applies a DC voltage (an electric field) according to the input image signal S to the electrodes 25 and 26 via leads 27a and **27b**.

**[0036]** Next, an operation of the display device **100B** will be described with reference to Figures 8 and 9. Figures 8 and 9 are cross-sectional views illustrating a display state of the recording medium **1B** operated by the display device **100B**. It is assumed that the electrophoretic particles 15 are negatively charged and floating in the dispersion medium 14, as illustrated in Figure 6.

**[0037]** An operator attaches the recording medium **1B** illustrated in Figure 6 to the driver **2B**, as illustrated in Figure 7. In particular, the display side substrate 18 of the recording medium **1B** and the non-display

## SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

side substrate 12 are placed into contact with the plurality of vertical linear electrodes 25 and the plurality of lateral linear electrodes 26, respectively, of the driver **2B**. Thus, the display side substrate 18 and the plurality of vertical linear electrodes 25, and the non-display side substrate 12 and the plurality of lateral linear electrodes 26, are switched to a conductive state due to the anisotropic conductivity of the display side substrate 18 and that of the non-display side substrate 12, respectively.

**[0038]** In this state, when the image signal S is externally input, the power supply circuit 27 applies a DC voltage (an electric field) of the positive or negative polarity according to the image signal S to the vertical linear electrodes 25 and the lateral linear electrodes 26 via the leads 27a and **27b**. Then, as illustrated in Figure 8, the electrophoretic particles 15 located between the electrodes 25 and 26 (with a positive DC voltage being applied to the vertical linear electrodes 25 and a negative DC voltage being applied to the lateral linear electrodes 26) migrate in the dispersion medium 14 to gather along the positively charged vertical linear electrodes 25, whereas the electrophoretic particles 15 located between the electrodes 25 and 26 (with a negative DC voltage being applied to the vertical linear electrodes 25 and a positive DC voltage being applied to the lateral linear electrodes 26) migrate in the dispersion medium 14 to gather along the positively charged lateral linear electrodes 26.

**[0039]** From outside of the display side substrate 18, the color of the electrophoretic particles 15 (white in

## SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

this embodiment) is seen in regions (pixels) where the electrophoretic particles 15 have gathered along the vertical linear electrodes 25, while the color of the dispersion medium 14 (blue in this embodiment) is seen in regions (pixels) where the electrophoretic particles 15 have not gathered. Thus, images consisting of two colors, i.e., white and blue, are visually displayed on the side of the display side substrate 18. Due to the image memory property, it is possible with no power supply to continuously display a still image on the side of the display side substrate 18 for a long period of time even after the connectors 17 and 22 are disconnected, as illustrated in Figure 9. Therefore, a plurality of still images can be compared with one another by exchanging only the recording media **1B** while using the same driver 2B, thereby producing a plurality of still images one after another.

**[0040]** The display device **100B** having such a structure according to the second embodiment provides similar effects as those provided by the display device **100A** according to the first embodiment. In particular, an electric field in a pattern according to the image signal can be applied to the recording medium **1B**, thereby producing a plurality of still images to be compared with one another with a simple and inexpensive structure comprising a single driver **2B** and a plurality of recording media **1B**. Moreover, since the recording medium **1B** does not have a group of electrodes arranged in a matrix or a plurality of vertical or lateral linear electrodes, the recording medium **1B** has a simple and inexpensive structure, thereby providing a simpler and less expensive structure for producing a plurality of still images.

## SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

Furthermore, since the non-display side substrate 12 and the display side substrate 18 are in contact with dispersion system 16, a high resolution image can be produced with a minimum applied voltage. Moreover, since a combination of the plurality of vertical linear electrodes 25 and the plurality of lateral linear electrodes 26 is employed as the electrode combination for applying an electric field to the dispersion system 16, it is possible to conduct matrix two-dimensional driving and thus to write an image to the recording medium 1B at a high speed. Furthermore, since the non-display side substrate 12 and the display side substrate 18 are each formed by an anisotropically conductive member having both a substrate function and an electrode function, it is possible to simplify the structure.

[0041] Figure 10 is an outlined perspective view illustrating an electrophoretic display device according to the third embodiment of the present invention. In the display device 100C the substrates 20 and 24 of the driver 2B of the display device 100B according to the second embodiment are coupled to each other with a hinge so that the device can be flipped open, with the power supply circuit 27 being provided inside one of the substrates (the substrate 24 in this example).

[0042] The present invention is not limited to the above-described embodiments, but various other embodiments may be possible. For example, in the first embodiment, the non-display side substrate 12 of the recording medium 1A and the side of the driver 2A facing the non-display side substrate 20 may be transparent so that they can be used as the display side. In such a case,

**SHUSAKU YAMAMOTO**

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

the display side substrate 11 and the planar electrode 13 do not have to be transparent. However, if they are transparent, it is possible to display an image on both sides of the device. Moreover, in the first embodiment, the planar electrode 13 may be a plurality of vertical or lateral linear electrodes, and the group of electrodes 21 may be a plurality of lateral or vertical linear electrodes. Alternatively, the planar electrode 13 may be a group of electrodes arranged in a matrix, and the group of electrodes 21 may be a planar electrode. In such a case, transparent electrodes are used for the electrodes provided on the display side. Furthermore, in the second embodiment, the combination of the plurality of vertical linear electrodes 25 and the plurality of lateral linear electrodes 26 may be replaced with a combination of a planar electrode and a group of electrodes arranged in a matrix. In such a case, transparent electrodes are used for the electrodes provided on the display side.

[0043]

[Effect of the Invention] As described above, according to the present invention, the electrophoretic recording medium can be separated from the driver, whereby a plurality of still images to be compared with one another can be produced with a simple and inexpensive structure comprising a single driver and a plurality of recording media, rather than using a plurality of display devices each including a recording medium. It is possible to obtain a plurality of recording media displaying the same or different still images, and the recording media can be arranged in an array on a wall or a board, whereby they can be used for various display applications such



## SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

as various presentations including a presentation at a convention of an academic society. Moreover, since the anisotropically conductive electrode and the counter electrode are in contact with the dispersion medium, a high resolution image can be produced with a minimum applied voltage. Furthermore, when a combination of a planar electrode and a group of electrodes arranged in a matrix, or a combination of a plurality of vertical or lateral linear electrodes and a plurality of lateral of vertical linear electrodes, is employed as the electrode combination for applying an electric field to the dispersion system, it is possible to conduct matrix two-dimensional driving and thus to write an image to the recording medium at a high speed.

[Brief Description of the Drawings]

[Figure 1] A cross-sectional view illustrating a structure of an electrophoretic recording medium according to the first embodiment of the present invention.

[Figure 2] A plan view illustrating an important part of a non-display side substrate according to the present invention.

[Figure 3] A cross-sectional view illustrating a structure of an electrophoretic display device according to the first embodiment of the present invention.

[Figure 4] A cross-sectional view illustrating a display state of the electrophoretic recording medium according to the first embodiment of the present invention.

**SHUSAKU YAMAMOTO**

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

[Figure 5] A cross-sectional view illustrating a display state of the electrophoretic recording medium according to the first embodiment of the present invention,

[Figure 6] A cross-sectional view illustrating a structure of an electrophoretic recording medium according to the second embodiment of the present invention.

[Figure 7] A cross-sectional view illustrating a display state of the electrophoretic recording medium according to the second embodiment of the present invention.

[Figure 8] A cross-sectional view illustrating a display state of the electrophoretic recording medium according to the second embodiment.

[Figure 9] A cross-sectional view illustrating a display state of the electrophoretic recording medium according to the second embodiment.

[Figure 10] An outlined perspective view illustrating an electrophoretic display device according to the third embodiment of the present invention.

[Description of the Reference Numerals]

1A, 1B Electrophoretic recording medium

10 Spacer

11, 18 Display side substrate of electrophoretic recording medium

11a Inner surface of display side substrate of electrophoretic recording medium

12 Non-display side substrate of electrophoretic recording medium

**SHUSAKU YAMAMOTO**

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

12a, 18a Film  
12b, 18b Conductive particle  
13 Planar electrode  
14 Dispersion medium  
15 Electrophoretic particle  
16 Dispersion system  
17, 22 Connector  
20 Non-display side substrate of driver  
20a Surface of non-display side substrate of driver  
21 Group of electrodes arranged in a matrix  
21a Insulative region  
23, 27 power supply circuit  
24 Display side substrate of driver  
24a Surface of display side substrate of driver  
25 Vertical linear electrode  
26 Lateral linear electrode  
26a Insulative region  
28 Hinge  
100A, 100B, 100C Electrophoretic display device  
S Image signal

SHUSAKU YAMAMOTO

Your Ref: 2108/2

Japanese Laid-Open Publication No. 10-48673

[Abstract]

[Problems] To provide an electrophoretic recording medium and an electrophoretic display device capable of producing a high resolution image and allowing for comparison among a plurality of still images with a simple and inexpensive structure.

[Means for Solving the Problems] A recording medium **1A** can be separated from a driver **2A**, whereby a plurality of still images to be compared with one another can be produced with a simple and inexpensive structure comprising a single driver **2A** and a plurality of recording media **1A**. Since a non-display side substrate 12 having an anisotropic conductivity in the thickness direction thereof and a planar electrode 13 are in contact with a dispersion system 16, it is possible to produce a high resolution image with a minimum applied voltage. When a combination of a planar electrode and a group of electrodes arranged in a matrix, or a combination of a plurality of vertical or lateral linear electrodes and a plurality of lateral or vertical linear electrodes, is employed as the electrode combination for applying an electric field to the dispersion system 16, it is possible to conduct matrix two-dimensional driving and thus to write an image to the recording medium **2A** at a high speed.